METHODOLGY FOR RADON PRESENCE INVESTIGATION IN MINE GALLERIES. CASE STUDY: *BĂIȚA BIHOR* REPOSITORY

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Radon brings an important contribution to natural radiation dose received by population. This contribution rises, in certain areas, up to a level of 90 to 95% leading to an exposure to natural radiation a lot higher than normal. People working in mining facilities or other closed areas with high radon concentration are exposing themselves to a very high dose of radiation in some cases this dose being 10 times higher than normal.

This paper addresses the problem of determining radon accumulation in Repository galleries at Baita Bihor using a special device. The device used has two determination methodologies, each one of them having their benefits and limitations. Using an extended set of experimental sessions and sampling point's variations of radon concentration analysis will be one, outlining the best methodology for radon determination, considering also the gallery structural and use properties.

It will also consider other parameters that have a direct implication in the variation of the concentration of radon in the mine galleries. We will measure also the atmospheric parameters such as pressure, temperature, relative humidity and we will observe radon concentration based on their variation.

Keywords: Radon, measurement, radiation

1. Introduction

Romanian National Radwaste Repository (DNDR) is intended for final disposal of low and intermediate level waste as this solution was taken into consideration also by other nations [1]. It was designed in 1983 and built according to initial project until 1985.

Repository is located in a complex of galleries built in an ex Uranium Mine situated in a relatively remote mountainous area, the nearest human settlement being Baita Plai small mining settlement; about 2 km west of the landfill site Bihor Mountains.

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Actual repository is arranged along two main galleries (50 and 53) including their already built transversal galleries for disposing the drums with conditioned radioactive waste.

From radiation protection point of view, U238 and its decay products are of major concern for uranium mining industry due to the large abundance of U in natural uranium [2]. The entire spectrum of decay products of is found in the ore depending on the age of the deposit (thus imposing a viable determination method [3] since the area is of higher risk for radon accumulation and production), which has important bearing on secular equilibrium status of the ore [2].

External gamma level and inhalation exposure due to radon (Rn222), its short-lived progeny and long-lived alpha activity associated with ore dust constitute the major source of radiological hazard in uranium mines.

Monitoring of Radon concentration inside uranium mines [4-6] (including Romanian mine [7-8]) and in the environment has been a matter of concern since last several decades to minimize the extent of inhalation exposure of occupational workers and the public ([9], IAEA, 1992; ICRP, 1993, 2010). The underground investigation of radon presence and behavior [10] was thoroughly investigated worldwide.

2. Determination of radon concentration-sampling methodology

The Radon (Rn-222) gas concentration will be measured by the short living daughter products, generated by the Radon decay inside a measurement chamber. Directly after the decay, the remaining Po-218 nuclei become charged positively for a short period, because some shell electrons are scattered away by the emitted alpha particle. Those ions are collected by the electrical field forces on the surface of a semiconductor detector. The number of collected Po-218 ions is proportional to the Radon gas concentration inside the chamber.

Po-218 itself decays with a half-life time of only 3.05 Minutes and about 50% (particles emitted towards the detector surface) of all decays will be registered by the detector.

The equilibrium between the Radon decay rate and Po-218 detector activity is given after about 5 half-life times, say 15 Minutes. This time span defines the minimum achievable response time to a Radon concentration step.

Now, the decay chain is continued by the both beta emitters Pb-214 and Bi-214 followed by another alpha emitter, the Po-214. That means, each Po-218 decay causes one more detectable decay by the Po-214 which is delayed about 3 hours because of the superposed half-life times of those nuclides. The emission energies of Po-218 and Po-214 are different and therefore it is possible to separate both nuclides from each other by alpha spectroscopy.

The RTM1688-2 offers two calculation modes for the Radon concentration, one (Slow) includes both, Po-218 and Po-214 decays and the other one includes Po-218 only (Fast).

The advantage of the "Fast" mode is the quick response to concentration changes while the "Slow" mode gives sensitivity twice as high compared with the fast mode. The higher sensitivity reduces the statistical error of a measurement which depends on the number of counted decay events only.

3. Experimental sessions

In order to correctly take into account variations of atmospheric pressure, temperature and relative humidity, factors that in Romania are widely varying depending on the season, 2 experimental sessions were conducted to determine the changes in concentrations of radon.

First experimental session was conducted in order to determine the precise location in the galleries in which radon concentration is the highest. Usually this happens in places inaccessible for natural air currents. An important series of measurements was carried out. Following these sessions the location inside the mine galleries where Radon reaches this maximum concentration was determined. Measurements were made along the transport galleries and also in the most difficult points to reach by air of the galleries (gallery 50) and in the front of galleries 31/1 and 31/2. Radon concentration was measured in 12 points represented in Figure 1, these points being chosen as representative because they are located at the entrance of the repository, at the front of the empty transverse galleries or partially filled with radioactive waste packages and also on the entire length of the gallery 50 (point in which the radon concentration reaches the maximum level) and the farthest point of the transport gallery (Gallery 50).

The location of the measurements points according to their position inside the galleries are represented in Figure 1:

- Point 1 - 10 m away from the entrance in the transport gallery (gallery 50)
- Point 2 – in front of hose 1
- Point 3 – in front of gallery 9/1 si 9/2
- Point 4 – in front of gallery 11/2
- Point 5 – in front of gallery 13/1
- Point 6 – in front of gallery 15/2
- Point 7 – in front of gallery 17/2
- Point 8 – in front of gallery 53
- Point 9 – in front of gallery 23/1 si 23/2
- Point 10 – in front of gallery 27/1 si 27/2
- Point 11 – in dreptul galeriei 31/1 si 31/2

- Point 12 – in capatul galeriei 27/2

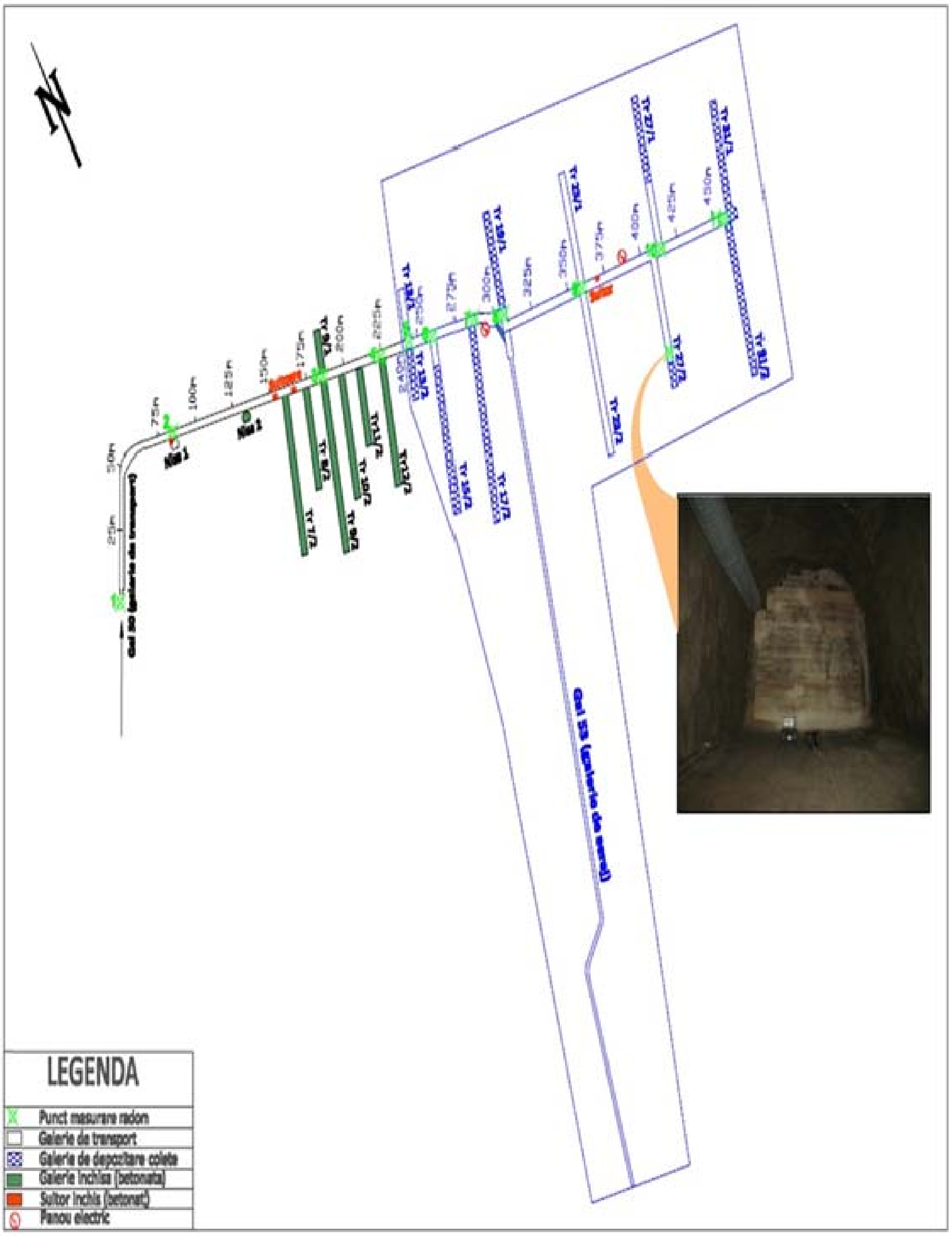

Fig. 1. Location of the measurements points of the radon on the repository sketch

The measurements of the Radon concentrations performed inside the Romanian National Radwaste Repository (DNDR) Baita-Bihor from 9 untill 13 July 2012.

The measurements were performed in 2 sessions: measurements performed along the transport gallery 50 and measurements performed in the furthest point of the transport gallery (gallery 50), in front of the galleries 31/1 and 31/2.

3.1. Measurements performed along the transport gallery

This experimental session was the very first step and the most important. During this session we determined the natural transport of radon inside mine galleries and we also determined the point where radon accumulation reaches the highest concentration. On 5-th of July, at 12:00 o'clock, the repository ventilation was started for two hours. On 9-th of July, at 16:18 (at 98 hours from ventilation stop) first measurement was conducted. In each of the above mentioned positions (points), starting with the entrance in the gallery 50, a set of 3 measurements was conducted. Each measurement lasted, each, for 15 minutes. Environmental conditions (pressure, temperature and relative humidity) were also monitored and recorded for the whole period the experiments were conducted.

Determinations of radon concentration are shown in Figure 2.

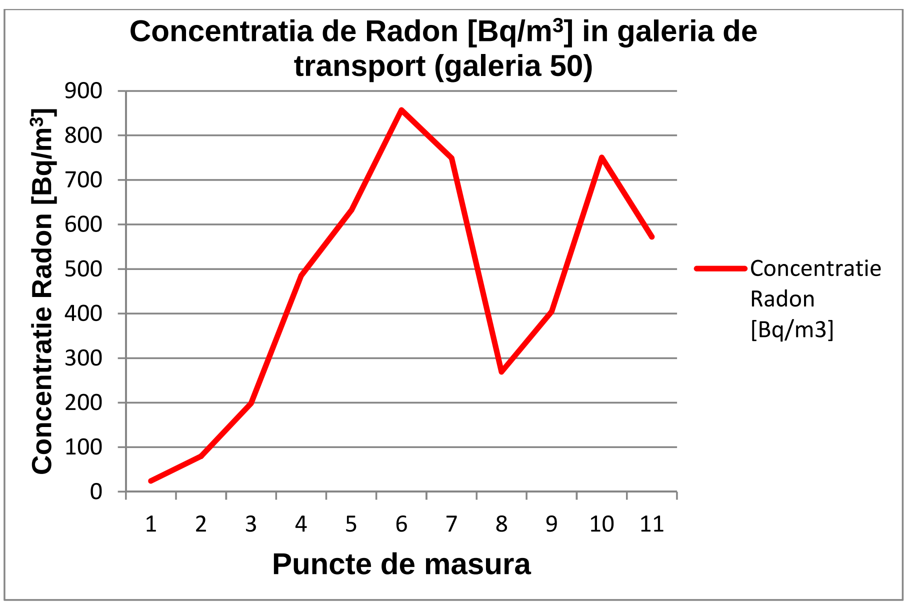

Fig. 2.Variatia concentratiei de Radon in galeria de transport (galeria 50)

Remarks

In point 1, positioned outside the repository, our device registered a radon concentration lower than the lowest detectable value (AMD) - 25 Bq/m3.

There is an increase in the radon concentration as we move towards the center/end of transport gallery (Gallery no. 50) - points 2-6.

In Point 8, located near the ventilation gallery (Gallery 53), there is a relatively large decrease in the concentration of radon due to natural circulation of air through the galleries (see Figure 2). Also, there is a decrease in the concentration of radon in points 7 and 9, located on both sides of the ventilation gallery (gallery no. 53).

3.2. Measurements performed in the furthest point of the transport gallery (gallery 50), in front of the galleries 31/1 and 31/2

On 05.07.2012, at 12:00 ventilation system was started in the repository for 2 hours. On 09/07/2012 and 10/07/2012 between the hours of 4:18 p.m. and 3:33 radon concentration measurements were made as described below. Furthermore, measurements were also carried out in the most remote point of gallery 50, at the front of the galleries 31/1 and 31/2. These measurements were undertaken for a period of about 75 hours.

Adopted measuring methodology:

– The equipment was set on “Fast Mode”, air pump working cycle: continuous.
– Between 3:39 PM and 5:21 PM (1 hour and 42 min) a total of 13 measurements of radon concentration were performed. The duration of each measurement was 6 minutes;
– At 5:20, the repository ventilation system was turned ON until 07:20 PM; during this time were conducted a series of 20 measurements of 6 minutes each for radon concentration;
– In the interval 7:21 - 8:21PM (1h), there were conducted a total of 10 measurements of 6 minutes each for radon concentration;
– Starting at 8:21, the device was set to conduct measurements at intervals of 1 hour; the equipment was set on “Slow Mode”, There have been conducted a total of 70 measurements until dated 13.07.2012 at 6:21AM;

Important remarks: It was chosen an interval of 6 minutes to measure the Radon concentration before turning on the ventilation system, during the ventilation was running and also for an hour after the ventilation was turned off, because we wanted to emphasize, that for the same measuring interval of 6 minutes, the ventilation system is having an effect on the accumulation of Radon.

The important difference between Slow mode and Fast mode is that the uncertainties are much smaller in the Slow mode case (between 9%-15%) than Fast mode (25%-100%)

The Radon measurements in these intervals, for the furthest point of the transport gallery (gallery 50), are represented in the Figure 3.

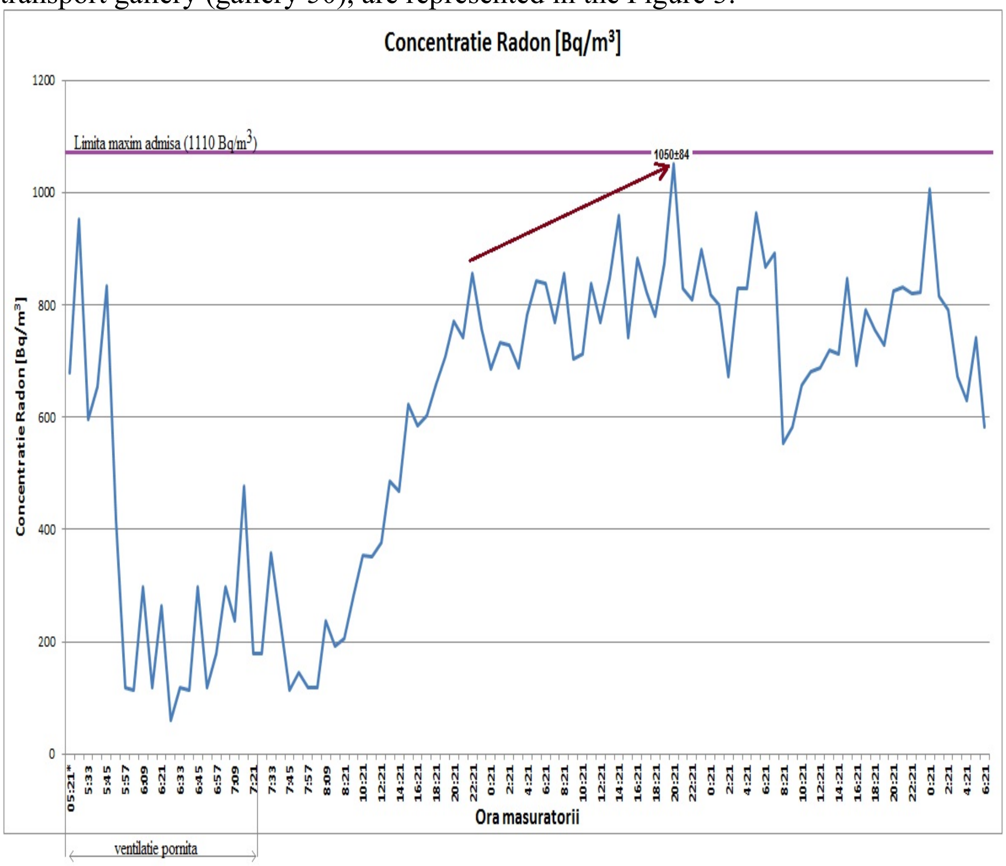

Fig. 3. The evolution of Radon concentration (end point of the transport gallery-50)

Remarks

Measurements of radon concentration in this phase were started after an interval of 108 hours and 40 minutes after stopping the ventilation system of the repository.

The average of 13 measurements of radon concentration - every measurement having a duration of six minutes - is (678.2 ± 298.4) Bq/m^3, being below the maximum allowed limit for the operating personnel - 1110 Bq/m^3 regulated by the norm [1].

After turning off the ventilation of the repository, in the first 40 minutes we can observe no significant increase in concentration of the radon activity. Then, there is a relatively constant increase of radon activity concentration for 14 hours (between the hours of 8:21 and 22:21 on 10.07.2012), the growth rate of the concentration is about 50 $Bq/m^3/h$.

We can observe periods of growth and sudden decrease of radon activity concentration which can be explained by natural air convection that appeared in the gallery due to:

- The tubes of the repository ventilation system are located near the end of the measuring point;
- Sudden drops are recorded at around 7 AM possible due to temperature variations outside the repository which can cause appearance of air currents in galleries 50 and 53; these air currents can influence radon concentration measurement in selected areas;

Radon concentrations recorded during the 71 hours of continuous measurements, after the 2 hours of ventilation, do not reach the maximum allowable limit of 1110 Bq/m^3 by the law [1].

4. Final remarks

The aim of this study was to measure the concentration of radon inside the galleries of DNDR Baita Bihor repository to demonstrate the proper operation of the ventilation system and to test if the designed parameters were met in order to protect the operating personnel. The repository was designed and constructed with a ventilation system which aims to maintain radon concentration during the disposal operations of the radioactive waste packages below the limits imposed by regulations. The aim of the study was achieved because the radon concentration measurements observed during the operation of ventilation were below the limits imposed by regulations, protection the operating personnel being assured.

We use two different modes, Slow and Fast mode in order to outline the effects of repository ventilation system on the radon accumulation. For these reasons, measurements have been performed on every 6 to 60 minutes. When we wanted to see the rapid accumulation of Radon inside the galleries we use the Fast mode and we measured for 6 minutes, while when we wanted to outline the accumulation of Radon for a period of days, we measured for 60 minutes each and we observed that the "Fast" mode is the quick response to concentration changes while the "Slow" mode gives sensitivity twice as high compared with the Fast mode (from 25% - Fast mode to 9% Slow mode).

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